Evaluation Monitoring for Stormwater Runoff Monitoring and BMP Development

G. Fred Lee, Ph.D., P.E., D.E.E. and Anne Jones-Lee, Ph.D.
G. Fred Lee & Associates
El Macero, California
PH: 916-753-9630
FX: 916-753-9956

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Abstract

This report covers the development and application of evaluation monitoring to highway, urban area and street stormwater runoff water quality management. A discussion is presented on the need for an alternative approach to the conventional approach of evaluating the water quality impacts of highway and urban area stormwater runoff on receiving water quality. Information is presented on the background to the development and application of site-specific studies (evaluation monitoring) that are conducted on the receiving waters for stormwater runoff that identify real water quality use impairments in these waters that are caused by chemical constituents and/or pathogenic organism indicators in the stormwater runoff.

The evaluation monitoring program is designed to replace the conventional "water quality" monitoring programs that are used for measuring the chemical constituents in highway, urban area and street stormwater runoff. It is widely recognized that conventional runoff water quality monitoring provides little in the way of useful information that can be used to evaluate the impact of stormwater runoff on the beneficial uses of the receiving waters for the runoff. Evaluation monitoring serves as a technically valid, cost-effective basis for BMP development that replaces the conventional approach that is used to develop stormwater runoff water quality BMPs. The conventional BMP development approach assumes that detention basins, grassy swales, various types of filters, etc. are effective BMPs in controlling real water quality use impairments due to heavy metals, organics and other constituents in highway and urban area stormwater runoff. However, it is now well-known that particulate forms of heavy metals and other constituents that are removed in conventional stormwater runoff BMPs do not adversely impact the beneficial uses of the receiving waters for the runoff. The particulate forms of heavy metals and other constituents are in non-toxic, non-available forms. Therefore, their removal in a detention basin will not be of benefit to the beneficial uses of the receiving waters for the stormwater runoff.

Basically, the evaluation monitoring program shifts the funds that are used for end-of-the-pipe runoff monitoring to site-specific, highly directed studies designed to find real water quality use impairments of the receiving waters for the stormwater runoff. When such use impairments are found that are due to highway, urban area or street runoff, then BMPs are developed that control the input of the pollutants, i.e. those constituents that cause impairment of the beneficial uses of the receiving waters for the stormwater runoff to the maximum extent practicable. The

uses of the receiving waters for the stormwater runoff to the maximum extent practicable. The focus of BMP development is on source control which limits the amount of pollutants entering the highway, urban area and street runoff at their source, rather than trying to treat the stormwater runoff. The evaluation monitoring approach is in accord with current regulatory requirements for highway, urban area and street stormwater runoff water quality management.

The evaluation monitoring program is designed to be a cooperative program in which the stormwater dischargers, regulatory agencies and those concerned about the water quality use impairment of the receiving waters for the stormwater runoff work together to formulate and implement the evaluation monitoring program in the most technically valid, cost-effective manner for utilization of the financial and other resources available.

A generic application of the evaluation monitoring approach for the development of stormwater runoff water quality management BMPs for a new highway is presented. This highway is being constructed without the conventional BMPs such as detention basins and/or filters. Instead, a critical evaluation has been made of the potential water quality problems that could arise from chemical constituents and pathogenic organism indicators in the highway stormwater runoff on the designated beneficial uses of the receiving waters for this runoff. When the highway becomes operational in the year 2000, site-specific studies will be conducted of each of the receiving waters for the highway runoff to determine what effect, if any, the highway runoff has on the designated beneficial uses of the receiving waters for the stormwater runoff. Consideration is given to such impacts as aquatic life toxicity, excessive bioaccumulation of hazardous chemicals in aquatic organisms, sanitary quality that impacts contact recreation and/or shellfish harvesting, excessive fertilization, oil and grease and litter accumulation, siltation, etc. Two types of stormwater runoff discharge situations are considered. One of these is a river; the other is an estuarine bay.

If the highway stormwater runoff is found to be a significant contributor to the impairment of the beneficial uses of these receiving waters, then the transportation agency responsible for managing highway stormwater runoff impacts will work with the regulatory agencies and others to develop best management practices that will control the impaired beneficial uses to the maximum extent practicable. The focus of the BMP development program will be on source control to limit the amount of the pollutants that enter the highway runoff at their source, rather than trying to develop structural treatment works for treating the highway runoff.

Introduction

The approach that is typically used to assess the "water quality impacts" from highway, street and urban area stormwater runoff (HSUA) is to monitor stormwater runoff by collecting a few samples of runoff at the edge of the drainage area from two to three storms per year and analyzing these samples for a suite of conventional potential pollutants, such as the heavy metals, petroleum hydrocarbons, PAHs, nutrients - N and P, total solids, suspended solids, enteric pathogenic organism indicators, etc. The results from these analyses are compared to US EPA (1987) water quality criteria/standards that have been established by regulatory agencies for the runoff receiving waters. If an exceedance of a water quality standard is found in the receiving waters, then the waterbody is said to be "impaired," and efforts are made to control the chemical constituents and pathogenic organism indicators, such as fecal coliforms, in the HSUA stormwater runoff through the use of BMPs to the maximum extent practicable. Traditionally, detention basins, grassy swales and other vegetative areas, oil-water separators and other structural BMPs are used to "treat" HSUA stormwater runoff. However, there is growing recognition that the traditional approach for assessing water quality impacts of chemical constituents in HSUA stormwater runoff is not technically valid and can lead to waste of public and private funds pursuing control of chemical constituents that ultimately have no impact on the designated beneficial uses of the receiving waters.

Problems with Current Regulatory Approaches

It has been known since the 1960s that many of the chemical constituents in stormwater runoff from urban areas are in particulate, non-available, non-toxic forms. Until recently, the development of BMPs for HSUA stormwater runoff focused on hydraulic considerations in the design of detention basins, etc. and failed to properly consider the aquatic chemistry and aquatic toxicology of chemical constituents in HSUA stormwater runoff as they relate to actual water quality issues of concern to the public. Further, the managers of traditional stormwater runoff water quality management programs often incorrectly assumed that the exceedance of a water quality standard in the runoff represented a significant impairment of the designated beneficial uses of the receiving waters for the runoff.

Those familiar with how US EPA water quality criteria and state standards based on these criteria were developed have known since the early 1970s that these criteria and standards are based on worst-case or near worst-case assessment of the potential impacts of chemical constituents on aquatic life-related beneficial uses of waterbodies. They also know that frequent substantial exceedances of water quality standards caused by HSUA stormwater runoff can occur without adversely affecting the aquatic life-related beneficial uses of a waterbody. As discussed by Jones-Lee and Lee (1994), Lee and Jones (1991a) and Lee and Jones-Lee (1993a, 1994a, 1995a,b,c,d), as well as in references contained therein, this arises from the situation that many of the constituents of greatest concern in HSUA stormwater runoff, such as heavy metals, are in particulate, non-toxic forms.

A second critical factor causing the exceedance of water quality standards in stormwater runoff to not necessarily represent an impairment of water quality is the short-term, episodic nature of runoff events compared to the aquatic organism exposure conditions that were used to develop the water quality criteria/standards. Aquatic organisms can be exposed to greatly elevated concentrations of toxic - available forms of constituents for short periods of time without adverse impacts. Typically, the criteria development approach involved exposures of organisms lasting several days to several weeks or more. In a typical HSUA stormwater runoff situation, toxic - available forms would normally be rapidly diluted in the receiving waters below concentrations adverse to aquatic life.

Complications Due to US EPA Independent Applicability Policy

Beginning in the early 1980s, the US EPA adopted implementation approaches for the Agency's water quality criteria and state standards which focused on total chemical constituents. Further, the Agency adopted the Independent Applicability Policy which required that numeric, chemically-based water quality standards had to be met in the receiving waters for wastewater discharges independent of whether the chemical constituents were in toxic - available forms (Lee and Jones-Lee, 1995e,f).

This Independent Applicability Policy has led to highly unreliable reporting of the water quality impacts of chemical constituents in HSUA stormwater runoff (Lee and Jones-Lee, 1996a). The US EPA and the states are required by Section 305(b) of the Clean Water Act to submit biennial reports on the quality of the nation's waters as part of the National Water Quality Inventory. These reports are submitted to Congress and provide the basis for establishing priorities for Congressional action on water pollution control programs. The most recent of these reports (US EPA, 1995a,b) follows the approach that was adopted by the US EPA several years ago of instructing states to report as impaired waterbodies any waterbody in which the concentrations of constituents exceed water quality criteria/standards in the region where the runoff enters the waterbody.

Lee and Jones-Lee (1996a) have discussed the technically invalid approaches that have been used by the US EPA in its National Water Quality Inventory for assessing the water quality significance of HSUA stormwater runoff. Every two years the US EPA's Report to Congress ranks "Storm Sewers/Urban Runoff" (*"Runoff from impervious surfaces including streets, parking lots, buildings, lawns, and other paved areas."*) as one of the leading causes of water quality impairment in the US. This ranking, however, is artificially high due to the use of exceedances of water quality criteria/standards as a basis for determining "impaired" waterbodies due to urban and highway runoff. The Agency through its biennial reports to Congress on the quality of the nation's waters has significantly overpresented the severity of the problem to Congress about the significance of HSUA stormwater runoff-associated constituents as a cause of water quality impairment in the nation's waters. This is especially true for any waterbodies which are ranked as "impaired" based on total concentrations of heavy metals rather than dissolved metals. As discussed herein, HSUA runoff contains elevated concentrations of particulate forms of heavy metals which do not impair the quality of receiving waters for the runoff.

The basic problem with the US EPA's National Water Quality Inventory is the same problem that occurred with those who have been developing traditional structural BMPs for

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HSUA stormwater runoff where it is assumed that any exceedance of a water quality standard in the runoff represented a significant impairment of the designated beneficial uses of the waterbody receiving the runoff. While exceedances of water quality standards in HSUA stormwater runoff waters are common, the impairment of the designated beneficial uses of a waterbody associated with these exceedances (real water pollution) is rare. For aquatic life-related beneficial uses the numbers, types and characteristics of desirable organisms in the receiving waters for the HSUA stormwater runoff must be significantly impaired before there is a real water quality problem associated with the exceedance of these standards. Such impairments are not being found in the studies of receiving waters for stormwater runoff from highways. The failure to focus on real water quality use impairments has led to significant over-regulation of chemical constituents in point and non-point source discharges.

Over-Regulation of Heavy Metals

One example of over-regulation resulting from a failure to focus on actual use impairment is the determination that a water quality use impairment exists when the total concentrations of heavy metals in runoff waters result in an exceedance of a water quality standard at the point which the heavy metals enter the receiving waters for the runoff. This problem has been compounded by lack of focus of regulatory programs on the appropriate forms of heavy metals.

It has been known since the late 1960s that particulate forms of heavy metals are non-toxic and non-available (NAS/NAE 1973). However, in the 1980s the US EPA's implementation of heavy metal criteria and state standards based on total heavy metals resulted in many states failing to adopt water quality standards for heavy metals. This eventually led Congress to adopt a National Toxics Rule which required that all states adopt water quality standards for heavy metals and other potentially toxic constituents.

The significant over-regulation that is occurring under the implementation of the National Toxics Rule has recently led the US EPA to change its approach to the regulation of heavy metals by focusing on toxic - available forms rather than total concentrations. The US EPA announced this approach as its official policy for implementation of the National Toxics Rule in the May 4, 1995 Federal Register (US EPA, 1995c). As a result, highway runoff BMPs, such as detention basins, which focus on removing particulate forms of heavy metals are now officially recognized as being technically invalid approaches (Lee and Jones-Lee, 1995g).

The US EPA's recent adoption of regulatory approaches based on dissolved forms of metals does not represent a new understanding of these issues. This was essentially the approach that was recommended by the National Academies of Science and Engineering in their Blue Book of Water Quality Criteria (NAS/NAE, 1973). It is also now beginning to be understood that even regulating dissolved forms of heavy metals represents over-regulation for many types of discharges due to the fact that many of the so-called dissolved forms are non-toxic and non-available as a result of the metals being present as complexes or colloids.

Heavy metals are not the only constituents which are being over-regulated; the same problem occurs with many organics, nutrients, etc. In general, regulating chemical constituents based on total concentrations is not an efficient approach to the problem and tends to divert or otherwise consume capital needed for the investigation and control of actual beneficial use impairments in receiving waters.

Control of Pollution vs. Achieving Standards

In 1990, the US EPA as part of adopting the national urban stormwater quality management program (US EPA, 1990a), recognized that significant over-regulation could occur if NPDES-permitted HSUA stormwater runoff was required to meet water quality standards at the point of discharge into the receiving waters. The Agency, in adopting the national urban stormwater management program, established the requirement that NPDES-permitted stormwater dischargers must control pollution caused by the discharges to the maximum extent practicable using BMPs. The Agency did not define what was meant by "maximum extent practicable" nor did it establish required BMPs. It did, however, define "pollution" as an impairment of the designated beneficial uses of the receiving waters for the permitted stormwater runoff.

Koorse (1995) has reviewed from a legal perspective the development of the regulatory background of the US EPA's Final Rule governing the regulation of stormwater runoff water quality from industrial and urban areas. He points out that there has been considerable confusion on how best to manage the water quality impacts of stormwater runoff-associated constituents.

At this time there is no requirement that HSUA stormwater runoff be treated to achieve water quality standards in the runoff waters. Further, in California the inappropriateness of requiring NPDES-permitted HSUA stormwater runoff to meet water quality standards (objectives) in the receiving waters was recognized by the Water Resources Control Board when a 10-year exemption from meeting these standards/objectives was granted to all NPDES-permitted HSUA stormwater runoff dischargers in April 1991. While that exemption no longer exists because of the court decision voiding the April 1991 objectives and the associated Inland Surface Water Plan and Enclosed Bays and Estuaries Plans, it is expected that with the re-promulgation of these plans, which is currently underway, this exemption will again be adopted.

In addition, the United States House of Representatives, as part of reauthorization of the Clean Water Act, proposes to allow a 15-year period of exemption from meeting water quality standards in permitted urban stormwater discharges. These proposed exemptions are based on the recognition that the application to stormwater discharges of the current water quality criteria/standards significantly over-regulates HSUA stormwater runoff. In an effort to correct this problem, the currently proposed Clean Water Act revisions provide $100 million to support US EPA research designed to develop appropriate wet weather criteria/standards that would be specifically designed to regulate HSUA stormwater runoff without significant over-regulation of permitted discharges.

Water Quality Impacts of Stormwater Runoff

Studies on Highway Runoff Impacts

Korbriger (1984a,b), Korbriger and Gupta (1984) and Korbriger and Geinopolos (1984) conducted studies for the Federal Highway Administration on the characteristics of highway runoff. While these studies are often cited as sources of information on the potential pollutional impacts of highway runoff, a review of the details of these studies shows that they did not distinguish between chemical constituents in highway runoff and those constituents which impair the designated beneficial uses of the receiving waters for the runoff. This was a significant deficiency in these studies in that while elevated concentrations of chemical constituents were found in the runoff, the studies did not include any evaluation of whether these constituents were present in toxic - available forms and whether the elevated concentrations of the constituents in highway runoff relative to US EPA water quality criteria and state standards occurred for a sufficient period of time in the receiving waters to be adverse to the beneficial uses of these waters.

Kerri *et al.* (1985) and Racin *et al.* (1982) have also presented information on pollutant loads from highway runoff. These studies also did not distinguish between chemical constituents in highway runoff and pollutants, i.e. those materials that impair the beneficial uses of a waterbody.

Driscoll *et al.* (1990) reported on "pollutant loadings and impacts of highway stormwater runoff." A review of this report shows that while information is provided on constituent concentrations in highway runoff, the authors failed to evaluate whether the chemical constituents in the highway runoff were in toxic-available chemical forms and would be present for sufficient duration at "excessive" concentrations in the receiving waters to be adverse to aquatic life and other beneficial uses of the receiving waters for the runoff.

Driscoll *et al.* utilized the event mean concentration of a highway stormwater runoff event to "characterize" the potential impacts of the chemical constituents in highway stormwater runoff. While this approach reduces the data obtained in monitoring a particular or series of runoff events to a single value, it is a highly unreliable approach for assessing water quality impacts of highway and other area stormwater runoff. As discussed by Lee *et al.* (1982) and Lee and Jones-Lee (1995a) aquatic organisms respond to concentration of toxic - available form duration of exposure relationships. The event mean concentration approach does not adequately or reliably incorporate key information that has to be available to determine whether excessive concentrations of heavy metals or organics, etc. in highway runoff relative to water quality standards are adverse to aquatic life-related beneficial uses.

The event mean concentration in addition to failing to focus on toxic - available forms also fails to properly consider the duration of exposure impact relationships that must be incorporated into a reliable analysis of the impacts of stormwater runoff. Overall, the studies of Driscoll *et al.* do not provide the information needed to reliably assess whether the runoff of chemical constituents from highways represents a potentially adverse impact on the beneficial uses of the receiving water for the runoff.

Stenstrom and Strecker (1993a,b) used similar approaches to those of Driscoll *et al.* to estimate the so-called chemical pollutant loads to Santa Monica Bay from highway and street runoff from the Santa Monica Bay watershed. While the results of their investigations were presented as "pollutant" loads, in fact, they should have been labeled "chemical constituent" loads. According to tradition, technical validity and the US EPA's (1990a) stormwater quality management regulations, a pollutant is a constituent that impairs the beneficial uses of the waterbody. It is not possible to use either event mean concentrations or total mass of constituents from highway or street runoff to estimate the pollution that will occur in the receiving waters for the runoff. The inappropriateness of the Santa Monica Bay Restoration Project in developing the management plan for the restoration program in which the Stenstrom and Strecker (1993a,b) results are used as a basis for formulating best management practices has been discussed by Lee (1995). The implementation of this proposed plan involves the development of over $40 million in structural BMPs to primarily control heavy metals in HSUA runoff. This is being done without finding a real water quality use impairment in Santa Monica Bay that is caused by these heavy metals. As discussed by Lee (1995), there is obvious need to find a real water quality problem in Santa Monica Bay first and then develop a restoration plan to control this problem in a technically valid, cost-effective manner.

Al-Kazily *et al.* (1995) have prepared a report for Caltrans concerned with a review of stormwater runoff monitoring from Caltrans highways. In a discussion of the conventional stormwater monitoring approach, Al-Kazily *et al.* state,

> *"The disadvantage of this approach to the storm water runoff management program is that, lacking good information about the potential problems in a specific receiving water, the problem is presumed to exist and money may be spent unnecessarily."*

They further state,

> *"Careful planning is important to ensure that known problems are tackled first while efforts are made to determine whether actual problems exist at other locations. The discharger is encouraged to prioritize efforts in both of these areas."*

In using stormwater monitoring to assess the impact of receiving waters, Al-Kazily *et al.* state,

> *"Identification of adverse impacts on receiving waters should be a cooperative effort between the dischargers in each watershed; however, coordination with municipal agency monitoring is needed."*

The Al-Kazily *et al.* (1995) report to Caltrans supports the development of an evaluation monitoring approach of the type being developed for a highway in which real water quality use impairments are found and then site-specific source control measures are developed to control the real use impairments associated with highway runoff.

It is now being found that where there is toxicity in urban stormwater and highway runoff, this toxicity appears to be due to agriculture and/or urban use of pesticides, such as diazinon. The heavy metals and other organics in HSUA stormwater runoff are not being found to be toxic to aquatic life. In some cases, such as in the Sacramento, California area, the spraying of orchards with diazinon in the winter causes HSUA stormwater runoff to be toxic to aquatic life at considerable distances from the point of application - spraying due to airborne transport of the diazinon. Diazinon is an organophosphorus pesticide that is highly toxic to zooplankton. Studies by Connor (1995), Domagaiski (1995), Kuivila (1993), USGS (1993), Kuivila and Foe (1995), MacCoy *et al.* (1995), and Foe (1995a,b) have shown that orchard or other area-derived diazinon causes runoff waters from the area to be toxic for several weeks for considerable distances downstream in the Sacramento and San Joaquin Rivers and in the Sacramento - San Joaquin River Delta system.

It appears now that an appropriate BMP to control diazinon toxicity in the highway runoff is through source control. Since diazinon is dissolved, it is obvious that the conventional highway stormwater BMPs, such as detention basins, will have no effect on the diazinon-caused aquatic life toxicity since diazinon would not be removed in detention basins or filters. Those who manufacture, sell or use diazinon and other pesticides that become part of HSUA stormwater runoff, as well as runoff from the orchards and other agricultural or rural lands, must be able to control the use so that there is no significant toxicity to aquatic life in the receiving waters for HSUA stormwater runoff. Highly specific source control BMPs of this type will likely be the primary mechanism by which potentially significant water quality problems can be effectively addressed and controlled for a variety of constituents that are found to cause water quality use impairments from highway runoff.

Recent Findings Regarding Urban Stormwater Runoff Impacts

In 1991 the American Society of Civil Engineers Urban Water Resources Research Council sponsored the Engineering Foundation Stormwater Conference. This was part of a series of conferences that have been held every couple of years devoted to urban runoff issues.

The 1991 conference was devoted to an assessment of stormwater runoff impacts on receiving waters (Herricks, 1995). A review of these proceedings shows that there are few documented cases where the chemical constituents in stormwater runoff from highways and urban areas have been found to be significantly adverse to the designated beneficial uses of the receiving waters for this runoff.

Pitt (1995) in these conference proceedings has presented a review of some of the literature on the biological effects of urban stormwater runoff. Most of the "effects" are based on chemical concentrations and are not real biological effects. These "effects" fail to consider toxic - available forms of chemical constituents in making the evaluation of the true impact of the urban stormwater runoff-associated constituents.

Herricks, editor of the proceedings, states,

"...best management practices need to be holistic, and that any control strategy needs to be a reasoned application based on scientific understanding, not rule of thumb practice."

Davies (1995) presented a review of many of the issues that need to be addressed in evaluating and controlling non-point source runoff impacts. He states,

"It is generally agreed that NPS [nonpoint source] *problems are unique and complex, and they will not be resolved as easily as the relatively simple treatment and standard compliance approaches used in the PS* [point source] *program. NPS programs will require development and application of innovative and imaginative control strategies, and the program will cost much more than the PS program."*

The general conclusion from the conference proceedings is that there has been far too much use of rule of thumb - standard practice approaches used in stormwater quality evaluation and management. Instead, there is need to focus on finding real water quality problems and solving them in a technically valid, cost-effective manner.

In August 1994, the Engineering Foundation held a stormwater NPDES-related monitoring needs conference which focused on the current state of knowledge related to the monitoring of HSUA stormwater runoff for water quality impacts. Urbanos and Torno (1994), in an overview summary of the conference, discussed that at this time very little is known about the water quality impacts of urban stormwater runoff. They state,

"If we are to acquire this understanding, we must stop wasting monitoring resources on the 'laundry list' type of monitoring encouraged or required by our current regulations. We must instead move towards well-designed and adequately funded national and regional scientific study programs and research efforts."

The logical, common-sense, technically valid and cost-effective approach for managing real water quality use impairments (pollution) caused by HSUA stormwater runoff is to first find a real water quality problem in the receiving waters for the runoff, determine the specific cause of this problem and develop site-specific source control methods to control the problem to the maximum extent practicable. This is the approach imbedded within the evaluation monitoring program that is proposed as the basis for managing water quality impacts due to stormwater runoff from a highway or street.

Evolving Changes in Stormwater Management and Monitoring

The California State Water Resources Control Board/American Public Works Association Stormwater Quality Task Force has recently initiated an effort to review the appropriateness of current stormwater quality monitoring and management approaches. It has been concluded that current monitoring approaches focusing on measuring chemical constituents in stormwater runoff provide little useful information that can be used to develop technically valid, cost-effective BMPs. The Task Force's Stormwater Monitoring Committee has concluded that there is need to shift the emphasis of the monitoring programs from runoff waters to the receiving waters in which efforts would be devoted to defining real water quality use impairments associated with the constituents in the runoff waters.

Recently, the US EPA (1995d) announced an "Advanced Notice of Proposed Rulemaking on the Water Quality Standards Regulation." The purpose of this Rulemaking is to re-examine the approach that was adopted over 10 years ago for developing and implementing water quality criteria and standards. One of the areas that will be specifically addressed as part of this Rulemaking is the regulation of urban and highway stormwater runoff. The Agency has indicated that it is considering developing wet weather criteria/standards that would address the specific problems associated with trying to use the current national water quality criteria as a basis for developing a regulatory approach for managing stormwater runoff quality.

Another area that the Agency indicated that it will address as part of the proposed Rulemaking is the Independent Applicability Policy. Consideration is being given to changing this Policy so that exceedances of chemically-based water quality criteria and standards can be over-ridden by biological effects-based criteria/standards and assessments. Of particular concern is the use of ambient water toxicity tests and/or receiving water aquatic organism assemblage information to determine whether the chemical criteria are over-estimating the impacts of chemical constituents in the stormwater runoff on the beneficial uses of the waterbody.

In summary, the current approach for regulating stormwater HSUA runoff is changing. The approach of measuring concentrations of constituents in runoff waters and then assuming that any exceedance of water quality criteria/standards represents an impairment of a designated beneficial use is being replaced by a site-specific, waterbody assessment of use impairment

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approach in which the focus of stormwater runoff water quality BMP development is devoted to controlling real water quality use impairments of significance to the public.

Development of the Evaluation Monitoring Program

Presented below is a summary of the key components of evaluation monitoring that should be used to determine whether HSUA stormwater runoff is causing a significant adverse impact on receiving water water quality and, therefore, there is need for a BMP to control HSUA stormwater runoff characteristics.

Aquatic Life Toxicity

Aquatic life toxicity is one of the areas of concern in evaluating the impact of HSUA stormwater runoff on receiving water quality. HSUA stormwater runoff contains concentrations of heavy metals and other constituents above those levels that are potentially toxic to aquatic life under worst-case conditions of 100% available forms and extended duration's of exposure. In order to evaluate whether the potentially toxic regulated chemicals which occur in runoff at concentrations above water quality criteria/standards are toxic in the receiving waters and to evaluate whether there are unregulated chemicals such as diazinon and other pesticides used in agricultural crops and in urban areas that can cause toxicity in receiving waters for HSUA stormwater runoff, it is necessary to directly measure toxicity in the receiving waters.

Davies (1995) in a discussion of "Detecting Toxicity Problems in Urban Runoff" states,

> *"Outside of a major fish kill in a receiving water stream, how would toxicity problems be detected? Attempts to analyze water from these systems for all possible toxicants would be extremely difficult and very expensive. Biomonitoring methods should first be used to determine if toxicity exists using, for example, the water flea* (Ceriodaphnia dubia) *as a test organism. Screening tests for acute toxicity can be conducted in two days, or a more sensitive life cycle test in seven days. Once toxicity has been established in a particular drainage system, biomonitoring can be used to locate and identify potential sources. With knowledge of types of activities or industries in the defined area, the kinds of potential toxicants can be narrowed and selective analyses performed. Once a toxicant(s) has been identified and attributed to a particular source, control can be implemented through normal regulatory channels."*

Recently, de Vlaming (1995a,b) of the California Water Resources Control Board staff has conducted a comprehensive review of the reliability of toxicity testing using acute or chronic tests in predicting water quality use impairments that are manifested as impaired aquatic organism populations. There are many situations where chemical composition of waters in which potentially toxic elements exceed US EPA water quality criteria do not reliably predict the water quality impacts in the receiving water for a wastewater discharge. This situation has led to the development of Whole Effluent Toxicity (WET) tests. de Vlaming reported that toxicity measurements on an effluent have been found to predict biological community impacts in the receiving waters for the effluent about 70% of the time. The reliability of the toxicity tests for estimating in-stream biological responses was improved when toxicity tests were conducted with ambient water and when the exposure conditions that organisms would experience in the ambient waters were duplicated in the toxicity test. Overall, de Vlaming concludes that the

> *"Available literature yields a compelling, weight of evidence, demonstration that the WET, and other indicator species, toxicity test results are accurate qualitative predictors of instream biological community responses."*

de Vlaming also indicated that in August 1995 the Society for Environmental Toxicology and Chemistry held a "Pellston" workshop devoted to the reliability of effluent toxicity tests in predicting water quality impacts in receiving waters. The participants in the workshop were experts in this field. While the proceedings of this workshop will not be published until the summer 1996, according to Denton (1995), the workshop participants came to the same conclusion as de Vlaming on the reliability of toxicity tests in predicting biological community impacts.

de Vlaming's review provides considerable support for the validity of the evaluation monitoring assessment of toxicity in which multiple species short-term chronic toxicity tests are used on ambient waters in which the duration of exposure and dilutions that occur in the receiving waters for stormwater runoff are simulated in the test conditions. It can be expected that if toxicity that persists in the receiving waters for stormwater runoff is found under these conditions, that there would be adverse impacts on the biological populations in these waters. Under these conditions the specific cause of this toxicity should be identified through a TIE. Further, in accord with current regulatory requirements, if the cause of toxicity is urban area or highway runoff, then BMPs need to be implemented to control the toxicity to the maximum extent practicable.

The evaluation monitoring program approach focuses on assessing toxicity in the receiving waters for the stormwater runoff. Rather than measuring heavy metals in runoff which are of importance because of their potential aquatic life toxicity in the receiving waters, toxicity in the receiving waters is measured before, during and after a stormwater runoff event. This approach is in accord with Davies' (1995) previously discussed recommendation for assessing the potential toxicity associated with non-point source runoff.

Measurement of toxicity in the runoff waters does not necessarily translate into significant toxicity in the receiving waters for the runoff. Caution should be exercised in assuming that the toxicity measured in runoff waters results in significant toxicity in the receiving waters for the runoff that leads to an impairment of the designated beneficial uses. The US EPA (1991) in the Agency guidance for implementing the WET test results states, *"The regulatory authority must carefully look at the test protocols and all the data collected to determine if the facility is actually contributing to toxicity in the ambient water."*

The issue is not whether the HSUA stormwater runoff is toxic at the point of discharge; the issue with respect to beneficial use impairment of the receiving waters for the stormwater runoff is whether there is sufficient aquatic life toxicity for a duration and areal extent to be significantly toxic to aquatic life in the receiving water water column. Lee and Jones (1991a) discussed the approach that should be followed in evaluating the significance of HSUA stormwater runoff toxicity. As they discussed, toxicity measurements should be made over time within and near the discharge plume. These toxicity tests should mimic the duration of exposure and concentration time profile for aquatic organisms under the influence of the HSUA stormwater discharge.

Figure 1 illustrates a general sampling regime for stormwater discharges into rivers, lakes, bays and nearshore marine waters. The sampling program for a particular location should be developed based on information derived from following drogues released at the point of stormwater discharge that move with the ambient water/discharge water mixture. By sampling at various times along the drogue path, it is possible to estimate the rate of dilution that occurs in the ambient waters and therefore the times that should be used to estimate the duration of exposure of the test organisms in the toxicity tests to various concentrations of the stormwater discharge.

Since it is possible that the receiving waters for the runoff may also be toxic from other causes than the runoff of concern, it is important to determine the toxicity in the runoff water discharge plume and outside of it. Under these conditions, an assessment should be made of whether the runoff contributes sufficient toxicity for sufficient duration and areal extent in the receiving waters to be considered of significance in impairing the designated beneficial uses of the receiving waters. It is also important to understand how the toxic response in the toxicity testing procedures used compares to the toxic responses possible in the receiving waters for the runoff in evaluating potential toxicity found in runoff waters.

The focus of the toxicity measurements should be based on short-term, chronic testing using fish larvae and zooplankton. The US EPA has developed guidance manuals for freshwater and marine systems (US EPA 1994a,b, 1995e). Lethality, impairment of reproduction, and growth should be used as toxicity end points in the toxicity testing. Because of the inability to reliably interpret algal toxicity data, it is recommended that algal toxicity tests not be used for this purpose (Lee and Jones-Lee, 1994b).

Measurements should be made of the receiving waters' toxicity for selected storms each year representing the seasons in order to determine whether the HSUA stormwater runoff

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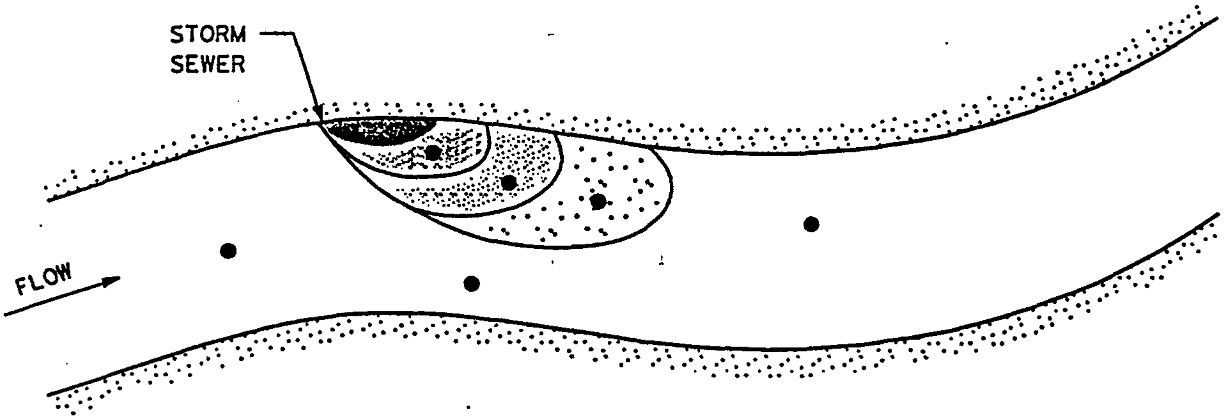
GENERAL CHEMICAL AND BIOASSAY SAMPLING REGIME
FOR URBAN STORMWATER RUNOFF



LEGEND

● SAMPLING SITE

FIGURE 1
URBAN STORMWATER RUNOFF SAMPLING REGIME
NO SCALE

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contributes significant toxicity to the receiving waters at any time during the year. There can be significant seasonal toxicity in HSUA stormwater runoff such as that found in the runoff waters in the Sacramento, California area where diazinon is used in the winter as a dormant spray in orchards and is carried for considerable distances through the air and causes toxicity in urban and highway stormwater runoff.

If the evaluation monitoring toxicity assessment shows that there is potentially significant toxicity in the receiving waters for the runoff, then TIE studies should be conducted to determine the specific source and cause of the toxicity. The US EPA has provided several guidance manuals on how to conduct TIE investigations (US EPA, 1989a,b,c,d, and Fava, *et al.*, 1989). These approaches have been used by a number of investigators to show that diazinon is a widespread cause of aquatic life toxicity in receiving waters for urban stormwater runoff.

Toxicity does not have to be present in all HSUA stormwater runoff to be adverse to receiving water water quality. Seasonal, widespread toxicity such as that which occurs associated with diazinon's use in orchards in the winter should be considered a significant adverse impact on receiving water water quality and require the development of BMPs to control this toxicity.

If no toxicity is found in the receiving waters or if the extent, duration and intensity of toxicity in the receiving waters is not sufficient to be significantly adverse to the numbers, types and characteristics of desirable aquatic life in the receiving waters for the stormwater runoff, it can be concluded that at the time of study, that all of the potentially toxic heavy metals, organics, etc., in the HSUA stormwater runoff as well as from all other sources, are non-toxic. Therefore, there would be no need for any additional BMPs to control potentially toxic chemicals in HSUA stormwater runoff as well as from all other sources of constituents for the waterbody.

If, however, potentially significant toxicity is found, then an assessment of the cause of this toxicity in the HSUA stormwater runoff should be conducted. Once the cause is known, the specific source(s) of the constituents responsible for the toxicity can be ascertained and potentially controlled at the source. An example of this type of situation has occurred where urban stormwater dischargers in many locations in the US have found that diazinon is a cause of aquatic life toxicity in the discharge waters. This toxicity occurs at various times of the year and is not related to the situation described above of the use of diazinon as a dormant spray in orchards in the winter in the Sacramento, California area.

The general toxicity in urban runoff being found that is caused by diazinon at various times of the year at many locations is due to its use on homes for structural treatment, control of insects in lawns, etc. At this time, the significance of this home use diazinon-caused HSUA stormwater runoff toxicity in adversely impacting receiving water water quality is not known since the studies necessary to define the degree, extent and duration of it in the receiving waters have not, to the knowledge of the authors, been conducted. There could be situations where this toxicity is rapidly lost in the receiving waters and is of no consequence in causing beneficial use impairment of these waters. In other situations, however, sufficient toxicity could persist for sufficient periods of time to be adverse to the beneficial uses of the receiving waters. Of particular concern would be small perennial urban streams, which maintain a desirable aquatic life habitat. Such streams could receive sufficient urban runoff derived toxicity to be adverse to aquatic life in the stream. It is this type of situation for which there is need to develop a BMP to control the diazinon or, for that matter, any other cause of toxicity in the receiving waters for HSUA stormwater runoff.

Bioaccumulation

Certain chemicals, such as chlorinated hydrocarbon pesticides, PCBs, dioxins and mercury, which are known or suspected to cause cancer in man and/or are neurotoxins, tend to bioaccumulate in edible aquatic organism tissue to a sufficient extent to cause regulatory agencies to issue a health advisory for the consumption of that organism. While, ordinarily, today the presence of large amounts of these chemicals in HSUA stormwater runoff is rare, it is important as part of any evaluation monitoring program to determine whether excessive bioaccumulation of chemical constituents that could lead to health advisories in the receiving waters for the runoff is occurring.

Also of concern is the bioaccumulation of chemicals in aquatic organisms which represents a significant threat to higher trophic level organisms, such as fish-eating birds and mammals, to endanger the health and reproduction of these organisms. The US EPA (1993a) has issued guidance on the development of wildlife criteria which is designed to protect wildlife from the consumption of aquatic life that contain excessive concentrations of hazardous chemicals. While this guidance was developed for the US - Canadian Great Lakes, it has applicability throughout the US.

The traditional approach for assessing bioaccumulation in HSUA stormwater runoff is to measure the concentration in runoff waters and then attempt to extrapolate from these concentrations to the concentrations that could be found in aquatic organism tissue. However, it is well-known that this approach is not reliable. The accumulation of many organics and mercury in aquatic organism tissue is basically a partitioning process in which the concentrations in the water or sediments equilibrate through partitioning with aquatic organisms. Typically, the factors controlling the uptake are variable from site to site and are controlled primarily by the amounts and types of carbon compounds in the water, sediments and the aquatic organism tissue fat content.

Unlike toxicity, excessive bioaccumulation is based on excessive concentrations of a specific chemical. Therefore, the chemical responsible for the health advisory is known.

However, chemical constituents exist in aquatic systems in a variety of chemical forms, only some of which can bioaccumulate in aquatic organism tissue to excessive levels. It is unreliable to assume that because an elevated concentration of a chemical constituent is found in aquatic organism tissue upon exposure to a particular source of the chemical, that that source will be responsible for causing or contributing to excessive bioaccumulation in aquatic organisms of concern to the public because of their use as food or because they are important food for higher trophic level birds or mammals.

While the US EPA and Corps of Engineers (US EPA/COE, 1991,1994) have developed some standardized equations for estimating bioaccumulation based on concentrations in water, these equations are not reliable for predicting uptake by organisms in various types of waterbodies. At this time, the only way to reliably assess whether constituents in HSUA stormwater runoff bioaccumulate in aquatic organisms to excessive levels is to measure the concentrations in the HSUA stormwater runoff-impacted receiving water organism tissue. If excessive concentrations are found relative to a properly developed "standard," then site-specific evaluations have to be made to determine whether the HSUA stormwater runoff is the source of the chemical of concern.

There is considerable confusion, and a number of inappropriate approaches are being used today by regulatory agencies and others in assessing whether excessive concentrations of a chemical are present in aquatic life tissue. It is important not to assume that an elevated concentration in organism tissue causes an adverse impact to that organism or higher trophic level organisms unless the necessary studies have been conducted which show that the accumulation of the chemical in the organism tissue is, in fact, adverse to the organism or higher trophic level organism. For human health, this would represent the development of a health advisory on the consumption of the organism edible tissue.

Some regulatory agencies, in an attempt to try to find some way to use chemical data associated with analysis of aquatic organism tissue, have contrived a variety of approaches which superficially appear to have some validity in the interpretation of bioaccumulation data. Concentrations above the mean or median concentration normally found in organism tissue, the so-called National Academy of Science values used only in California and a few other jurisdictions, are not valid for assessing the beneficial use impairment that a tissue residue represents.

Over the years, considerable attention has been given to attempting to evaluate the water quality and public health significance of tissue residues in various forms of aquatic life. After careful review, it is generally concluded that there are few chemicals where reliable information is available on what constitutes an excessive concentration of a chemical in aquatic organism tissue. Aquatic organisms and many mammals, including man, are known to accumulate a variety of fat-soluble chemicals in their tissue without any significant adverse impact on the organism and man. Therefore, the valid approach available today for interpreting bioaccumulation data is a Food and Drug Administration (FDA) Action Level or a US EPA or other agency risk-based human health advisory. Further, for human health advisories, it is important to focus bioaccumulation evaluation on edible tissue of organisms that are actually used as food and not on zooplankton, worms, or some lower trophic level organisms which are not used as food covered by the human health advisory.

The US EPA has recently developed a series of manuals on assessing excessive ioaccumulation of chemicals in aquatic life tissue (US EPA 1992a, 1993b, 1994c, 1995f). The US EPA has developed a risk-based approach for determining the allowable tissue levels of potential carcinogens and mercury that will protect the public who use these organisms as food. These guidance manuals should be consulted for further information on the evaluation of excessive concentrations of chemicals in edible aquatic organism tissue.

If excessive concentrations above health advisories or US EPA wildlife criteria based on tissue concentrations are not found in the receiving waters for appropriately tested aquatic organisms, then there is no need for further monitoring of chemical constituents in HSUA stormwater runoff for those chemicals that are of concern because of their potential to bioaccumulate to excessive levels. If, however, excessive accumulations of potentially hazardous chemicals are found, site-specific studies will likely require a combination of laboratory uptake studies which simulate receiving water conditions and field studies using caged organisms in the areas where HSUA stormwater runoff could likely be responsible for the excessive bioaccumulation. The US EPA/COE (1991,1994) provide information on conducting laboratory based bioaccumulation studies. Newbry and Lee (1984) have provided information on inexpensive cages that can be used for conducting such studies. It will be important to conduct these studies both within and outside but near the area of potential influence for the highway stormwater runoff to ascertain whether this runoff is a significant contributor to excessive aquatic organism tissue concentrations.

As with toxicity, site-specific BMPs can be developed to control those constituents in HSUA stormwater runoff which lead to the excessive bioaccumulation in aquatic organisms in the receiving water for the runoff.

Adverse Impacts of Sediment-Associated Constituents

It is possible that chemical constituents in HSUA stormwater runoff could accumulate in receiving water sediments and thereby cause a significant use impairment of these waters through sediment toxicity and/or serving as a source of chemicals that lead to excessive bioaccumulation in aquatic organism tissue. The accumulation of chemicals in sediments can be due to either particulate forms of the constituent in the HSUA stormwater runoff or dissolved forms in the runoff which become particulate in the receiving waters through sorption, precipitation and/or bio-uptake by lower trophic level organisms, such as algae, which die, settle and become part of the sediments.

A variety of chemical reactions occur in aquatic sediments which detoxify heavy metals and other constituents, rendering them inert. It would be, indeed, rare that heavy metals and many other constituents in urban stormwater runoff from highways, streets and residential areas, as well as most commercial and industrial areas, would be toxic in aquatic sediments to a sufficient extent to impair the designated beneficial uses of the waters associated with the sediments.

It has been known for over 25 years that it is not possible to use heavy metal concentrations in sediments to reliably predict water quality problems associated with heavy metals, organics and other constituents. It is necessary to use biological effects-based evaluations of potential water quality impacts (toxicity and bioaccumulation) in order to determine if heavy metals or other constituents in sediments are significantly impairing the beneficial uses of a waterbody.

Since the mid-1970s, the US EPA and the Corps of Engineers (COE) have been regulating excessive concentrations of chemicals in sediments associated with navigational waterway dredging and dredged sediment disposal as they may impact the beneficial uses of the waterbody in which the disposal takes place. Based on the research that was done in the 1970s under COE's Dredged Material Research Program, the US EPA and the Corps of Engineers adopted an effects-based approach involving direct measurement of sediment toxicity and estimates of bioaccumulation. In 1991, the US EPA and the Corps of Engineers updated their Testing Manual for ocean disposal of contaminated sediments (US EPA/COE, 1991). The Agency and Corps are now updating their freshwater dredged sediment disposal manual based on similar approaches to those that have been used for nearly 20 years (US EPA/COE, 1994). US EPA (1992b, 1993c) has published additional information on sediment quality evaluation procedures. A discussion of the development and use of these procedures is provided by Lee and Jones (1992) and Lee and Jones-Lee (1994c).

Biological effects-based techniques are well-established to determine whether potentially toxic constituents that accumulate in sediments are adverse to the waterbody in which the sediments are located. As with water column effects, the evaluation monitoring program should be conducted to define real water quality use impairments associated with any accumulated runoff-derived constituents in the receiving water sediments. Lee and Jones-Lee (1993b, 1994c,d) have reviewed issues pertinent to evaluating the water quality significance of chemical constituents in aquatic sediments. As they discuss, both aquatic life toxicity to a suite of sensitive aquatic organisms and bioaccumulation in aquatic organism tissue of chemicals that are of potential concern to human health and wildlife, should be evaluated as part of a biological effects-based sediment quality evaluation. Selected chemical analysis of the sediment should be made for the regulated chemicals such as heavy metals, PAHs and ammonia as well as for the constituents in aquatic sediments that tend to detoxify - immobilize regulated chemicals (TOC, sulfides, etc.) as part of the TIE evaluation conducted to determine the cause of the toxicity.

Similar approaches to those developed by the US EPA and COE could readily be used to address the issue of whether chemical constituents in HSUA stormwater runoff are responsible for significantly adversely impacting the beneficial uses of the waterbody receiving the runoff through accumulation of dissolved and particulate constituents in the runoff in the receiving water sediments. Toxicity tests, field bioaccumulation studies, and benthic aquatic organism assemblages (numbers, types and characteristics) can be used in a non-numeric, best professional judgment, weight-of-evidence triad to determine whether aquatic sediments in the vicinity and downstream of an HSUA point of runoff are a significant contributor to the impairment of the designated beneficial uses of the receiving waters for the runoff. Further information on this approach is provided by Lee and Jones-Lee (1993b).

It is not necessary to know the specific cause of sediment toxicity in order to determine if a particular section of highway or other area is contributing to sediment toxicity. Toxicity tests can be used to trace the origin of toxicity to its source for those situations where the toxic form of the particulate constituent is derived from stormwater runoff.

It is possible to conduct a sediment-based TIE to determine the cause of the toxicity for those sediments that are found to have sufficient toxicity to impair the beneficial uses of the waterbody. Ankley *et al.* (1991) have developed guidance on conducting TIEs on aquatic sediments. The information developed from the TIE can then be used to develop a technically valid, cost-effective approach for implementing stormwater runoff BMPs.

It is important to not try to use chemically-based approaches such as Long and Morgan values, McDonald values and AETs, for assessing water quality impacts of sediment-associated constituents. Such approaches are highly unreliable (Lee and Jones-Lee, 1994d). Sediment water quality impacts should be based on biological effects-based assessments (Lee and Jones-Lee, 1993b).

If significant water quality use impairments are found associated with sediment-associated constituents derived from HSUA stormwater runoff sources, then site-specific BMPs focusing on source control can be developed which will specifically address the dissolved and/or particulate constituents in the runoff that are responsible for the sediment constituent-associated impairment of the waterbody's beneficial uses.

It is important to understand that finding toxicity in aquatic sediments should not be interpreted to mean that this toxicity is a significant cause of a beneficial use impairment for the waterbody in which the sediments are located. Many aquatic sediments are naturally toxic due primarily to the growth of algae and other aquatic plants in the waterbody, which upon death, accumulate in sediments and exert an oxygen demand which uses up all dissolved oxygen (DO). The low DO conditions in sediments lead to the accumulation of ammonia and hydrogen sulfide, both of which are highly toxic to aquatic life. While these conditions occur naturally, the activities of man in a waterbody's watershed can increase the amounts of aquatic plant nutrients contributed to a waterbody and therefore the toxicity of the sediments.

The natural toxicity of sediments due to low DO, NH_3 and H_2S is not necessarily a significant factor in adversely impacting the designated beneficial uses of waterbodies. Many waterbodies with highly toxic sediments have highly desirable aquatic life resources. At this time, there is a poor understanding of the coupling between sediment toxicity and the impairment of the designated beneficial uses of waterbodies. Work needs to be done to understand how the control of constituents in HSUA stormwater runoff which accumulate in receiving water sediments causing or contributing to sediment toxicity influences the beneficial uses of waterbodies. Until this work is done, there can be little justification for developing BMPs to control chemical constituents in HSUA stormwater runoff because they accumulate in aquatic sediments.

Excessive Fertilization-Eutrophication

The excessive fertilization of waterbodies is one of the major causes of water quality use impairment. This impairment is manifested primarily as an impact on the aesthetic quality of waters where excessive algal and waterweed growth impacts the use for recreational purposes. For domestic water supplies, excessive fertilization leads to a number of problems such as increased taste and odors, shortened filter runs and increased trihalomethane precursors. As discussed by Jones and Lee (1982, 1986) and Lee and Jones (1991b), while increasing the fertility of a waterbody results in an overall increased fish biomass, increased fertility generally results in a deteriorated quality of fish where less desirable, rough fish, such as carp, become predominate. Lee and Jones (1991a) and Lee and Jones-Lee (1996b) have discussed the importance of evaluating the potential significance of HSUA stormwater runoff-derived nutrient loads compared to other sources of nutrients for a waterbody. Rast and Lee (1983, 1984) have provided guidance on how this can be accomplished.

Per unit area, highway, street and urban areas tend to export more nitrogen and phosphorus per year than most agricultural - rural lands. An important exception occurs with dairies and some other animal husbandry activities. There are situations where urban street runoff has caused excessive fertilization of small urban lakes (Lee and Jones, 1980). Ordinarily, however, excessively fertile waterbodies near urban areas and highways obtain most of their nutrients from domestic wastewater sources, agricultural and rural land runoff, the atmosphere and from nitrogen compounds in groundwater that discharge to the waterbodies.

There are several important issues that need to be addressed in developing nutrient-based BMPs for HSUA stormwater runoff. One of these is the need to focus the nutrient control program on those forms of nutrients (N and P) that can stimulate algal growth in the receiving waters. For most freshwater systems, the nutrient control program must be focused on algal-available phosphorus and not total phosphorus. Similarly for those waterbodies in which nitrogen is the chemical controlling algal biomass that develops in the waterbody, the control programs must focus on available forms of nitrogen compounds. While for most fresh waterbodies, phosphorus is the element limiting algal biomass, there are situations, however, such as Lake Tahoe in California - Nevada, where nitrogen is the limiting element controlling algal growth. Under these conditions, it is the algal available nitrogen in the HSUA stormwater runoff relative to other sources of these nitrogen compounds that must be evaluated. Lee and Jones-Lee (1994e) have reviewed the Lake Tahoe nutrient (nitrogen) source situation where they have reported that the most significant source of nitrogen compounds (nitrate and ammonia) is the atmosphere through direct precipitation on the Lake's surface. As they discussed, BMPs directed toward controlling nitrogen from associated land runoff will not be effective in controlling the excessive fertilization of Lake Tahoe that is occurring today.

For marine waters, it is typically the algal available nitrogen that is the key constituent in controlling algal biomass in the receiving waters, although there may be situations where phosphorus can become an important element in controlling algal growth in nearshore marine waters. A site-specific evaluation of the relative significance of nitrogen vs. phosphorus in controlling excessive fertilization of a waterbody must be made in order to determine whether algal-available forms of the controlling element present in HSUA stormwater runoff are significant contributors to the excessive fertility of the waterbody.

Lee *et al.* (1980) have provided guidance on the determination of available forms of aquatic plant nutrients in runoff waters and sediments. Basically, for nitrogen it is the nitrate plus ammonia as N plus part of the organic nitrogen in the runoff waters that become available in the receiving waters to support algal growth. For phosphorus, it is the sum of the soluble orthophosphate plus about 20% of the particulate phosphorus that is available to support algal growth in HSUA runoff. Site-specific determinations of available N and P can be assessed through the use of algal bioassays.

Lee and Jones (1988a) have provided guidance on the approaches that can be used to determine whether nitrogen or phosphorus is the key limiting element in controlling algal biomass in a waterbody. As they point out, a number of the approaches that are used such as the ratios of N and P in the waterbody are not necessarily reliable and can readily lead to incorrect conclusions on the significance of nitrogen or phosphorus in controlling algal growth. It is important to ascertain whether the proposed limiting nutrient is, in fact, decreased to algal growth rate limiting concentrations during peak algal biomass. If it is found that during the peak of the algal bloom the algae still have available to them surplus amounts of available forms of nitrogen and phosphorus, then these elements are not limiting the algal biomass.

It is also important to consider the hydraulic/morphologic characteristics of the waterbody (flushing time) receiving the HSUA runoff at various times of the year. If it is found that any nutrients added to the waterbody during one time of the year are effectively flushed out before the period of the year when excessive algal growth occurs, then the nutrients contributed to the waters during the non-growth periods are not contributing to the eutrophication-related water quality problems.

Further, a distinction should be made between eutrophication-related water quality problems which are manifested as excessive growths of planktonic algae vs. the growths of attached algae, attached and floating macrophytes and emergent vegetation. With respect to the latter, at this time there is a poor understanding of nutrient load - concentrations eutrophication response relationships.

Jones and Lee (1982,1986) have provided guidance on how to evaluate the potential benefits of controlling phosphorus inputs to a certain degree on the eutrophication-related water quality of a waterbody. They recommend the use of the Vollenweider-OECD eutrophication study results. These results provide the technical base upon which estimates can be made of the site-specific benefits associated with controlling phosphorus inputs to a waterbody to a certain degree relative to the total nutrient load to the waterbody. Lee and Jones (1986) have found that at least a 25% reduction in the total available phosphorus load to the waterbody must occur before a discernible improvement in the planktonic algal-related water quality will occur. At this time, similar relationships have not been developed for nitrogen. However, it is likely that at least the same magnitude of control of algal available nitrogen must occur before there will be a discernible improvement in eutrophication-related water quality of a waterbody due to nitrogen input control.

Except for small urban lakes which receive their nutrients almost exclusively from urban area runoff, there will be few situations where control of nitrogen and phosphorus inputs associated with urban street and highway runoff to a waterbody will result in an improvement in eutrophication-related water quality of the waterbody. This is because HSUA stormwater runoff-associated nutrients can rarely be controlled to a sufficient degree to reduce the total nutrient load to the waterbody sufficiently to cause a discernible impact on the eutrophication-related water quality of a waterbody.

It is sometimes stated that there is need to restrict the use of fertilizers on lawns, golf courses, highway right-of-ways and other areas in order to prevent excessive fertilization downstream from the point of HSUA stormwater runoff. The development of BMPs to restrict use of these fertilizers should only be done where it has been demonstrated that the current use is, in fact, causing a significant water quality problem in the receiving waters for the HSUA stormwater runoff and where it can be shown that the projected restrictions will result in the improvement of the eutrophication-related water quality downstream of the HSUA stormwater runoff discharge.

It is concluded that it will be rare that such restrictions would be beneficial to the eutrophication-related designated beneficial uses of waterbodies receiving HSUA stormwater runoff. The areas of greatest concern will be small urban lakes that only receive nutrients from

HSUA stormwater runoff. Typically, the amount of the algal-available aquatic plant nutrients derived from HSUA stormwater runoff is small compared to that derived from other sources such as rural runoff and domestic wastewater inputs.

For those few instances where aquatic plant nutrients in HSUA stormwater runoff are found to be a significant cause of eutrophication-related water quality use impairment, it would then be possible to develop site-specific BMPs to control the specific source of the available forms of the key nutrient that is contributing to the excessive fertility in the receiving waters. If this control is projected to be effective in bringing about an improvement in water quality, then such BMPs should be implemented to the maximum extent practicable.

Oxygen Demand

Frequently, HSUA stormwater runoff monitoring programs will include measurement of biochemical oxygen demand (BOD) and/or chemical oxygen demand (COD) as part of the monitoring of the runoff. While HSUA stormwater runoff can readily have measurable amounts of BOD, it is unlikely that this BOD will be of any significance in affecting the oxygen resources of the receiving waters for the runoff. As discussed above, however, the aquatic plant nutrients added to a waterbody, can be a significant source of nutrients that stimulates algal growth which, in turn, leads to oxygen depletion in a waterbody's sediments and for a stratified waterbody, its hypolimnion.

Site-specific evaluation of the oxygen resources of a waterbody should be conducted to determine if BOD associated with HSUA stormwater runoff is a significant contributor to the impairment of a waterbody's beneficial uses due to low DO. If such impacts are found, then appropriate BMPs can be developed to control the BOD input to the waterbody from HSUA stormwater sources. The approach that would be followed would focus on the specific sources of the high BOD materials in the stormwater runoff and then controlling the source of the high BOD materials.

Petroleum Hydrocarbons - Oil and Grease

This section focuses on the bulk effects of accumulated oil and grease and does not address the aquatic life toxicity of petroleum hydrocarbons present in petroleum products. Those problems are considered under aquatic life toxicity for the water column and sediments. The stormwater runoff from HSUA typically contains small amounts of petroleum hydrocarbons which can, under certain situations, cause water quality problems in receiving waters for the runoff.

In most situations, there is no need to try to treat the HSUA stormwater runoff to remove oil and grease since the small amounts of oil and grease ordinarily in this runoff do not cause significant water quality use impairments in the receiving waters. However, there are situations where petroleum hydrocarbons derived from oil and grease can be an important cause of water quality use impairments for HSUA stormwater runoff.

As part of the evaluation monitoring program, the receiving waters should be periodically visually examined to determine if there are areas where oil and grease from the HSUA stormwater runoff accumulate to a sufficient extent to be detrimental to aquatic life and other beneficial uses of the waterbody. Of particular concern would be fish spawning areas which accumulate sufficient amounts of petroleum hydrocarbons to be adverse to fish reproduction.

If the receiving waters are found to accumulate oil and grease from HSUA stormwater runoff to a sufficient extent to be adverse to the designated beneficial uses of the waterbody, then a site-specific BMP can be developed which would control the input of oil and grease to the maximum extent practicable and, if necessary, treat the runoff waters to remove the oil and grease to the extent necessary to prevent adverse impacts. Before expensive treatment is undertaken, however, attempts should be made to control the petroleum hydrocarbon contribution to the HSUA runoff based on source control activities. The most likely source of oil and grease in runoff is near the toll plazas. The runoff waters from these areas will be treated for oil and grease removal.

Aquatic Life Carcinogens

Aquatic life in some areas, especially associated with petroleum hydrocarbon refining and industrial processes that introduce large amounts of PAHs into a waterbody, has been found to have tumors, lesions and other illnesses associated with the chemicals that are carcinogens. While this is apparently not a problem associated with HSUA stormwater runoff, it would be important to examine some of the aquatic organisms in an area receiving such runoff to determine if they have tumors, liver or other organ lesions, abnormal organs, etc. that could be attributable to the runoff. If problems of this type are found that are tied to HSUA stormwater runoff, then site-specific BMPs can be developed to control at the source and, if necessary, treat the stormwater runoff to control the problem. This treatment would likely involve removal of petroleum hydrocarbons beyond that currently planned for the toll plaza area runoff. It is important to emphasize, however, that it is not anticipated that such treatment would be needed.

Sanitary Quality

HSUA stormwater runoff typically contains elevated concentrations of fecal coliforms and other organisms that are indicators of waterborne enteric pathogens. The sanitary quality (contact recreation - swimming, wading and shellfish harvesting) of the receiving water for HSUA stormwater runoff can be adversely impacted by fecal coliforms (total coliforms for shellfish). The development of BMPs for HSUA stormwater runoff to address the control of enteric pathogenic organism indicators such as fecal coliforms should be based on finding

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excessive concentrations of these organisms in receiving waters for the runoff that impair the use of these waters.

Excessive concentrations are usually manifested in beach or swimming area closures and/or restrictions on shellfish harvesting. If such closures and/or restrictions of use are present in receiving waters for HSUA stormwater runoff, it is necessary to determine whether the runoff is, in fact, a significant contributor to the frequency of closure - restrictions. If this situation is found, then it will be important to determine whether there are connections between the sanitary sewerage system and the stormwater sewerage system which allow domestic wastewaters to enter the stormwater system during runoff periods.

Lee and Jones (1991c) have reported on the results of a study conducted in Lubbock, Texas where an evaluation was made on the impact of urban stormwater runoff-derived fecal coliforms and streptococci on recreational water quality in the Yellowhouse Canyon Lakes. These lakes are a chain of small lakes in a city park that receive appreciable stormwater runoff from the urban area. It was found that immediately after a stormwater runoff event, the sanitary quality of these lakes decreased to the point where they were considered unsafe for contact recreation, such as swimming. However, within a week to two weeks after the runoff event, the water in the lakes again met sanitary quality standards for contact recreation. During this period there was sufficient removal of the fecal indicator organisms through die-off and sedimentation to reduce their numbers below the fecal coliform standards.

Often today there is an attempt to distinguish between fecal indicator organisms derived from humans vs. animals through determination of fecal coliform - fecal strep ratios in swimming area closure situations. If these ratios indicate that the fecal indicator organisms are derived from animal rather than human sources, then it is generally determined that there is less need for the closure of the contact recreation area. However, justification for this approach is highly questionable based on the fact that *Cryptosporidium* is derived, at least in part, from cattle and possibly other animals. This organism is becoming recognized as an important cause of enteric disease associated with domestic water supplies and contact recreation (Lee and Jones-Lee, 1993c, 1994f, 1995h). This is the organism that was responsible for causing approximately 400,000 people in Milwaukee, Wisconsin to become ill and about 100 people to die in a water supply waterborne epidemic in the spring of 1993. The source of this organism was believed to be from cattle where stormwater runoff waters containing cattle feces entered the Milwaukee raw water supply.

An area that is receiving increasing attention as a potential source of enteric pathogenic organisms is the use of reclaimed wastewaters for irrigation of ornamental shrubbery and other areas such as highway right-of-way shrubbery. As discussed by Lee and Jones-Lee (1995h), some regulatory agencies such as the California Department of Health Services (CA DHS) allows the irrigation of ornamental shrubbery and golf courses with reclaimed domestic wastewaters that have not been adequately disinfected to control enteric viruses and cyst-forming protozoans such as *Cryptosporidium.* Disinfecting a domestic wastewater to just meet fecal coliform standards does not provide adequate disinfection to necessarily kill all the pathogenic enteric viruses and protozoan cysts. The use of partially treated reclaimed wastewaters to irrigate shrubbery along highways, in parks, golf courses, etc. could lead to potential water quality problems associated with HSUA stormwater runoff.

The BMP for such problems would involve more appropriate disinfection of the reclaimed wastewaters before reuse. Lee and Jones-Lee (1995i) have recently provided guidance on the water quality monitoring program that should be conducted to determine whether reclaimed domestic wastewaters represent important sources of fecal organisms that would represent a significant threat to the sanitary quality of a waterbody. They recommend that in addition to monitoring for fecal coliforms, the monitoring program should include measurement of enteroviruses and cyst forming protozoans such as *Cryptosporidium* and *Giardia.*

If it becomes necessary to disinfect HSUA stormwater runoff in order to prevent this runoff from causing impaired water quality in the receiving waters for it, it will be important to remove the residual disinfectant, such as chlorine, to be sure that it is not adverse to aquatic life in the receiving waters.

Groundwater Recharge

In many areas, HSUA stormwater runoff recharges groundwater basins. The chemical constituents and pathogenic organisms in the runoff can potentially be a threat to groundwater quality. While in most instances the constituents in HSUA stormwater runoff will not significantly alter the potential for the receiving waters to impair the uses of groundwater, there may be unusual situations where groundwater quality could be impaired by constituents in HSUA stormwater runoff. Typically, the additional loads of constituents in runoff water are such that they do not significantly change the concentrations of constituents of concern for groundwater quality through the recharged waters. Further, many of the constituents with elevated concentrations in HSUA stormwater runoff are in particulate forms which are removed from the recharge waters as the receiving waters plus the runoff waters percolate into the aquifer system.

Some of the dissolved constituents in highway runoff will be sorbed into the vadose zone (unsaturated) and saturated zone of the aquifer and thereby not cause groundwater quality - use impairment. The aquifer mobile fraction of the chemical constituents in the runoff waters such as nitrate, chloride, sodium, etc. are normally present in HSUA stormwater runoff waters at concentrations that do not represent threats to groundwater quality. An exception to this situation is detention - infiltration basins where the constituents in the HSUA stormwater runoff are not diluted in the receiving waters for the runoff. Under these conditions, it is possible to build up sufficient concentrations of some chemical constituents in the recharge waters to be a threat to groundwater quality.

At a location where HSUA stormwater runoff is recharged directly or is a significant component of receiving waters that recharge an aquifer, such as in areas where infiltration of stormwater is used for stormwater runoff management, a site-specific evaluation should be made to determine whether the recharge waters are adversely impacting the quality of the waters in the aquifer. Typically, this is best done by sampling the groundwaters immediately under the recharge areas and down groundwater gradient of the recharge point. If excessive concentrations of chemical constituents are found in the groundwaters that can be attributed to recharge, then evaluations should be made as to whether these constituents are derived to a significant extent from HSUA stormwater runoff.

A special area of concern with respect to groundwater pollution by stormwater runoff is the potential for accidental spills of chemicals to cause pollution of aquifer systems. It is important, as part of developing an accidental spill contingency plan, to be able to contain the spill as much as possible in areas in which there is low permeability aquifer materials or paved surfaces as a barrier between the spilled chemicals and the water table. Further, in the event of a spill, those responsible for managing HSUA stormwater runoff should be prepared to be able to quickly begin remediation of the contaminated parts of the aquifer to prevent the spread of the spilled chemicals through the unsaturated - vadose zone and into the water table.

Domestic Water Supply Water Quality

Since chemical constituents and pathogenic organisms in HSUA stormwater runoff are threats to domestic water supply raw water quality, it will be important to evaluate whether stormwater runoff from these areas is significantly adverse to a water utility's use of a waterbody as a raw water supply. For most water quality parameters, the evaluation monitoring approach discussed herein which focuses on defining real water quality problems of significance to aquatic life and recreational uses of waters will, in general, detect significant water quality problems for domestic water supplies. There are, however, some exceptions to this situation.

There are certain chemical constituents and pathogenic organisms in waters which are of concern because of their impact on raw water supply water quality. Examples would be low molecular weight organics which are potential carcinogens which do not bioaccumulate in fish tissue to a sufficient extent to cause health hazards for human consumption or consumption by higher trophic level organisms. Chemicals of this type are the VOC's (low molecular weight chlorinated solvents and volatile organics such as benzene).

A chemical that could become extremely important in affecting domestic water supplies but not other beneficial uses of waterbodies is arsenic. Dependent on the concentration that the US EPA selects as the new Maximum Contaminant Level (MCL) for arsenic as part of its current review process, arsenic could become one of the most important parameters influencing raw water quality. It is of concern because of its potential to cause cancer and other diseases in

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people. Some stormwater runoff studies have shown arsenic from urban areas to be at concentrations above some of the US EPA's proposed MCL's. In time, considerable attention will be given to specific sources of arsenic which cause a waterbody to have concentrations of arsenic that require treatment for use of the water for domestic water supply purposes. When this occurs, the sources of arsenic in HSUA runoff will need to be determined to ascertain if the elevated concentrations of arsenic in the runoff can be controlled at the source.

Another group of chemicals of potential concern are the trihalomethane precursors (dissolved organic carbon - DOC) that are derived from the decay of terrestrial and some forms of aquatic vegetation. Eventually, the US EPA and state regulatory agencies will be attempting to control sources of DOC for waterbodies in an effort to reduce the DOC content of the raw water. While various types of land use have differing DOC export coefficients (g of DOC/m^2/yr), insufficient information is available at this time to indicate that stormwater runoff from highways and urban areas is a particularly significant source of DOC. This is an area that needs attention in any evaluation monitoring program. Further information on evaluation and management of domestic water supply raw water quality is found in the review by Lee and Jones (1991d).

The impact of HSUA stormwater runoff on domestic water supply water quality needs to be considered from two perspectives: surface or groundwater-based water supplies. The basic issue is whether HSUA stormwater runoff introduces new constituents in sufficient amounts to be a significant threat to domestic and other water supply water quality. Both human health (hazardous chemicals and pathogenic organisms) and aesthetic quality should be considered, including taste and odor producing compounds, hardness, total dissolved solids (TDS) and other constituents that can impact domestic water supply water quality. In situations where there is already appreciable HSUA stormwater runoff contributed to a domestic water supply, the issue then becomes one of whether the additional load of HSUA stormwater runoff-derived constituents represents a significant additional load that either causes the water utility to start to have to treat to remove the constituents or to have to increase treatment costs to remove the additional load of constituents.

For domestic water supplies that are based on groundwater sources, the issue becomes one of assessing the potential for HSUA stormwater runoff-derived constituents to adversely impact the groundwater that is recovered from the area where HSUA stormwater runoff-derived constituents are recharged into the aquifer system. While many aquifers have an appreciable ability to remove - "treat" chemical constituents in recharged waters through soil aquifer treatment, there is a potential for build-up of persistent chemicals and/or transformation products of treated chemicals within the aquifer system. As discussed by Lee and Jones-Lee (1993d, 1994g,h) concern must also be given to whether constituents in recharged waters could cause the aquifer to become contaminated to a sufficient degree to lead to the need for aquifer remediation in a Superfund-like program.

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All groundwater-based water utilities should be monitoring the characteristics of the recharged waters near the point of recharge to detect incipient water quality problems. HSUA stormwater runoff-derived constituents of potential concern should be added to the list of aquifer-based monitored parameters. Similarly, surface-based water supply systems should be conducting a detailed monitoring program of the raw water quality. If any of the HSUA stormwater runoff-derived constituents represent a threat to the surface water quality, groundwater or aquifer quality, then site-specific BMPs should be developed to control the constituents at the source or to treat the HSUA stormwater runoff to protect the water supply water quality.

Litter and Debris

HSUA stormwater runoff can carry appreciable quantities of litter and debris which can impair the use of areas receiving the runoff. A key part of evaluation monitoring is determination of whether litter and debris typically associated with HSUA stormwater runoff is present in the receiving waters to a sufficient extent to impair the uses of the waterbodies and their nearshore associated areas. If visual inspection of the receiving waters shows that areas of this type occur, then improved litter and debris control can be implemented to eliminate the use impairment that is occurring associated with the materials carried in the runoff.

Evaluation of the Impacts of Specific Chemical
Constitutents in Stormwater Runoff

The end-of-the-pipe stormwater discharge monitoring that has been done has shown that HSUA stormwater runoff in many parts of the US contains elevated concentrations of a variety of chemical constituents and waterborne pathogenic indicator organisms that represent potential threats that could impair uses of receiving waters for the runoff. As is well-known today, however, the characteristics of these constituents and stormwater runoff events greatly diminishes, and for some constituents eliminates any use impairment in the receiving waters associated with the elevated concentrations of the constituents in the runoff waters within a short distance in the receiving waters for the stormwater runoff discharge. The evaluation monitoring program is designed to screen the receiving waters from real use impairments due to the exceedances of water quality standards in the runoff waters by screening for significant persistent toxicity in the receiving waters associated with runoff events. If no toxicity is found in the receiving waters for the stormwater runoff associated with a runoff event, then there is no need to make measurements of specific chemicals that are of concern because of their potential toxicity. Similarly, by screening the edible aquatic organism tissue in the receiving water for excessive bioaccumulation, it is possible to rule out those regulated chemicals that represent threats of bioaccumulation.

If, however, significant toxicity or excessive bioaccumulation is found in the receiving waters that can be associated with stormwater runoff from HSUA, then site-specific studies can be conducted to determine the specific cause and source of the water quality problem. These, in turn, would lead to the development of BMPs that would specifically address the control of real water quality problems that are found. Lee and Jones-Lee (1996b) have recently presented a discussion on the need to use evaluation monitoring in the development of technically valid, cost-effective BMPs for HSUA stormwater runoff.

Since it will be difficult to break the habit of focusing monitoring programs on specific chemical constituents where the results are mechanically compared to water quality standards, irrespective of duration of exposure and available form considerations, it is important, that to the extent that specific chemical constituents are monitored in the receiving waters, that this monitoring determine whether there is a potentially significant increase in the receiving waters of potentially hazardous forms of the constituent which could be detrimental to receiving water quality. The receiving water monitoring program should specifically address whether the stormwater runoff causes a measurable increase in regulated chemicals. These measurements should be made close to the point of entry of the stormwater runoff into the receiving waters but outside of the physical mixing zone for the stormwater runoff and the receiving waters.

The physical mixing zone is not necessarily the same as the regulatory mixing zone that is often arbitrarily established associated with NPDES point source discharges. Typically for such discharges, current regulatory approaches prohibit exceedance of water quality standards outside the regulatory defined mixing zone. This approach leads to over-regulation of chemical constituents in point source discharges since the size of the mixing zone is less than that which could be allowed to protect the designated beneficial uses of the receiving waters without significant, unnecessary expenditures for chemical constituent control.

The physical mixing zone associated with stormwater discharge is the area of the waterbody receiving the discharge where mixing occurs within a short time after discharge. For streams and rivers, it is typically defined as the reach of the river where the concentrations of constituents in the receiving waters and the runoff are mixed to greater than 90%, i.e. the concentrations across the river that result from the discharge should not vary more than about 10%. For lakes, large rivers, estuaries and the ocean, the mixing zone can be defined in terms of the region of the receiving waters in which the time concentration profile for the discharge water plume is such that no adverse impacts on receiving water water quality would be expected because the planktonic aquatic organisms in the plume do not receive an excessive concentration - duration of exposure relationship for the potentially toxic constituents in the discharge. The focus in the evaluation is on short-term, acute effects within this mixing zone. The evaluation monitoring then considers whether longer-term, chronic effects arise from the specific chemical constituents of concern outside of this mixing zone.

If chemical measurements are to be used for specific constituents, then total recoverable and dissolved fractions should be measured, recognizing that the dissolved fraction of metals, organics, nutrients, etc., is the fraction that best estimates potential adverse impacts. While at this time the US EPA has only indicated that it will allow the dissolved fraction of certain metals in ambient waters to be used in regulatory programs, in time, the Agency will likely adopt similar approaches for other constituents which are potentially toxic to aquatic life in the receiving waters, such as organics. It is well known through work on sediment criteria development that the particulate fraction of organics, like the particulate fraction of metals, is not available and is non-toxic.

If measurement of the dissolved fraction of a regulated chemical which is of concern because of its potential to cause toxicity to aquatic life or to lead to excessive bioaccumulation within aquatic organism tissue shows potential water quality problems, then follow-up studies should be conducted to evaluate whether the apparent excessive concentrations represent potentially significant use impairments in the receiving waters for the runoff. This can best be done by conducting toxicity tests and/or determining whether excessive bioaccumulation is occurring in aquatic organism tissue for receiving water organisms. If no toxicity is found in the receiving water in properly conducted tests that reflect the concentration - duration of exposure relationships that occur in the receiving waters for this stormwater discharge, then it is possible to rule out the exceedance of the water quality standard/objective as representing a real water quality use impairment for potentially toxic chemicals.

If, however, significant toxicity is found in the receiving waters, then site-specific studies need to be conducted to determine the cause of the toxicity and whether it is due to constituents associated with stormwater runoff. Normally this can be ascertained based on measurements of toxicity within and outside of the runoff plume. Lee and Jones (1991a) have discussed approaches that can be used for following the runoff plume in the receiving waters where measurements are made within the plume and outside of the plume along a drogue path.

Any sampling that is done for specific chemical constituents should be done with "clean techniques" such as those described by the US EPA (1993d). It is now known that most of the heavy metal and some other chemical constituent data that have been collected on runoff waters and receiving waters over the last 15 years are unreliable due to the failure of those conducting the studies to properly sample and to protect the collected samples from contamination during sampling and sample handling. Clean techniques are necessary to avoid contaminating the samples and yielding artificially high values for chemical constituents of concern.

Aquatic Organism Assemblages

The evaluation monitoring program discussed herein focuses on utilizing biological effects-based test responses, such as toxicity tests, that can give an indication of a water quality use impairment that is occurring in the receiving waters for the HSUA stormwater runoff. The bottom line issue with respect to the development of BMPs to control aquatic life resource impairment is whether the numbers, types and characteristics of the aquatic organisms in the receiving waters for the HSUA stormwater runoff are sufficiently adversely impacted so that the public, who must fund remediation - control programs, finds that control of the constituents responsible for the use impairment through the implementation of BMPs to the maximum extent practicable should be implemented. In those situations where the testing procedures, such as ambient water toxicity tests, predict significant impairment as a result of finding widespread prolonged toxicity associated with a runoff event, the evaluation monitoring program should include examination of the numbers, types and characteristics of the biological organisms within the receiving waters to be certain that the toxicity tests have reliably predicted the adverse impacts.

The US EPA is developing biological criteria which are specifically designed to evaluate whether the numbers, types and characteristics of the organisms in a waterbody have been adversely impacted by input of chemical constituents. The agency has developed a biological criteria guidance manual that provides guidance in making this type of evaluation (US EPA, 1990b). Further, the Agency has recently revised its Water Quality Criteria Handbook which should be consulted for further information (US EPA, 1994d). It is important, however, in making an evaluation of this type, to clearly distinguish between the impact of habitat characteristics and physical factors, such as climate, flows, storms, etc., that may influence aquatic organism assemblages and those that are due to chemical constituents derived from HSUA stormwater runoff. Lee and Jones (1982) have provided guidance on how to utilize aquatic habitat information in determining whether chemical constituent input to a waterbody (streams and rivers) is adversely impacting the number, types and characteristics of organisms that could be present in the waterbody based on the waterbody's habitat characteristics.

Evaluation Monitoring Beyond Initial Evaluation

The initial screening evaluation monitoring discussed herein will detect significant water quality use impairments in the receiving waters for the stormwater runoff. After completion of the initial screening, there would be need to continue the evaluation monitoring program where ongoing studies would be conducted that are designed to try to detect subtle impacts of runoff-associated constituents on the beneficial uses of the receiving waters that are not detected in the initial screening. As real water quality use impairments are controlled and as additional information is gathered on the receiving waters, less obvious use impairments may become evident. Further, through the development of new chemicals and changes in the use of existing chemicals, it is possible that new water quality problems will develop in the future that do not exist now or are not recognized now. As more is learned about the impacts of chemicals on aquatic organisms, new adverse impacts are being found that need to be considered in any water quality evaluation. The traditional, end-of-the-pipe constituent monitoring will not reliably detect new water quality problems; however, the evaluation monitoring program which focuses on detecting receiving water impacts can detect the new problems and provide a technical base for their control.

It is envisioned that the evaluation monitoring program would be an ongoing program where all use impairments would not be addressed at one time. Instead, the expected use impairments of a waterbody would be prioritized in terms of importance to the public, and over a five year permit period, each of the potentially significant water quality use impairments would be addressed. This same type of use impairment would then be examined again at approximately five year intervals.

Evaluation Monitoring as Part of Watershed Water Quality Management

The State Water Resources Control Board and the Santa Ana Regional Water Quality Control Board as well as Orange County Environmental Management Agency are in the process of adopting a watershed-based water quality management approach for the various major waterbodies in the state and Orange County. Both the Santa Ana River system and Upper Newport Bay watersheds are part of a watershed water quality management programs. The evaluation monitoring program for the highway will provide support for the implementation of the watershed management programs. By determining the real water quality - use impairment for each of the waterbodies receiving the highway runoff and by identifying the cause and the source of the constituents causing the water quality impairment, it will be possible to help implement a technically valid watershed-wide management program. Those responsible for managing water quality for constituents derived from other parts of the watershed will ultimately become involved in similar kinds of water quality use impairment evaluation and management programs as those being developed for the highway.

Accidental Spill Containment

One of the areas of particular concern in developing BMPs for highway runoff is the containment of accidental spills of chemicals and fuel that occur on the highway or its shoulder. In developing BMPs for a highway, it is important to incorporate into the stormwater runoff management program approaches that can be readily used to contain accidental spills of chemicals that can occur in areas where the spill could rapidly enter a sensitive waterbody. Efforts should be made to assist the local transportation agency/stormwater management agency in implementing accidental spill containment contingencies through the design of emergency runoff control structures, such as easily implemented check-dams, stormwater outlet flow control devices, etc., to the maximum extent possible to prevent spilled chemicals and fuel from entering the waterbodies.

BMPs and Hazardous Wastes

Some of the structural BMPs that are being developed today for HSUA stormwater runoff, such as detention basins and filters, are accumulating sufficient concentrations of chemical constituents originally present in the runoff to cause the sediments that collect within the structures to be classified as a hazardous waste. It is important in designing and operating

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structural BMPs for HSUA stormwater runoff to consider whether the materials that accumulate within them are classified as hazardous wastes since such a classification greatly changes the cost of residue management. It is also important to design stormwater runoff conveyance structures, drop inlets, etc. so that they do not accumulate particulates in HSUA stormwater runoff that could be classified as a hazardous waste. While such classification is based on inappropriate, arbitrarily developed definitions evolving out of the federal and state regulatory agencies' approaches for managing hazardous wastes, this classification is costing some stormwater management entities large amounts of money, in managing as hazardous waste, the residues that accumulate within the stormwater management conveyance systems. It is important to note, that with few exceptions, these materials are not particularly hazardous to workers who may come into contact with them or to the environment. They are, however, hazardous wastes based on the arbitrary approaches that have been used to define hazardous wastes which consider how the materials would behave in a sanitary landfill, and therefore, must be managed as such unless a variance is issued exempting this type of management.

The Realities of Pollution Prevention

The notion which is sometimes advocated in water pollution control programs that every little bit of "pollution control" helps is not technically valid and can be detrimental to developing meaningful water quality management programs for a region. For every water quality pollution control program there should be developed, as part of its implementation, a clear, well-defined assessment of the receiving water designated beneficial use benefits that will accrue as a result of implementation of the pollution control program. Considering current fiscal limitations within the public sector, capital and maintenance expenditures must be focused on the most acute water quality problems rather than implementing sweeping but less intensive programs that are only partially effective or are non-effective.

An example of this type of situation occurs in HSUA stormwater runoff where detention basins have been adopted as a water quality BMP in which property developers, private, state and federal highway agencies and municipalities acquire lands and provide the maintenance for the development and operations of a detention basin that removes particulate forms of constituents in HSUA stormwater runoff. While detention basins can be justified if there is a significant erosion problem that needs to be controlled and cannot be controlled at the source where erosion is occurring, there is no valid justification for using detention basins to control particulate forms of constituents in HSUA stormwater runoff as a result of the US EPA's May 1995 adopted approach of focusing control programs on ambient water soluble forms of heavy metals. Detention basins and other structural BMPs, such as grassy swales, vegetative areas, etc., should only be constructed where there is a technically valid, well-founded, expected significant improvement in the designated beneficial uses of the waterbody for the HSUA stormwater runoff.

Frequently, today the advocates of pollution prevention programs focus their efforts on the control of chemical constituents such as heavy metals in storm water runoff without regard to whether the heavy metals in such runoff are in toxic-available forms. An example of this type of situation occurs in San Francisco Bay, where it is advocated that there is need to force the automobile brake pad manufactures to remove copper from the brake pads since the wear of the brake pads results in elevated concentrations of copper in highway and street runoff. However, it has been found that the copper in San Francisco Bay from all sources, including highway runoff, is not adverse to the beneficial uses of the bay waters. Therefore, the control of copper in automobile brake pads does not represent a control of a pollutant, i.e., a constituent that impairs use, but represents control of a chemical constituent that will have no impact on the beneficial uses of San Francisco Bay.

A similar situation exists today with respect to the Santa Monica Bay restoration program, where this program is directed toward the control of chemical constituents in urban stormwater runoff independent of whether these constituents have any impact on Santa Monica Bay water quality - beneficial uses. Such approaches can be wasteful of public and private funds and result in misdirecting pollution prevention programs to unimportant areas. It is important, therefore, in developing technically valid <u>pollution</u> prevention programs, to focus these programs on those constituents, i.e., specific forms of chemicals, which are, in fact, pollutants. This will require the use of an evaluation monitoring program of the type described herein in formulating and implementing the pollution prevention program.

Ecologically sensitive - important, currently un-impacted areas should receive particular attention in developing BMPs for HSUA stormwater runoff. Important fish and shellfish spawning areas that are not now receiving substantial amounts of HSUA stormwater runoff should receive special attention. For example, the oil and grease and other petroleum hydrocarbons from a new major highway that enters a pristine area stream that is used for salmonid reproduction where the hydraulic characteristics of the water would promote the accumulation of oil and grease in the spawning bed area, should be prime targets for BMP development to control oil and grease runoff from the highway.

Summary of Evaluation Monitoring Approach

Presented below is a summary of the key components of the evaluation monitoring approach to determine whether runoff-derived constituents from highway, street and urban areas are causing a significant adverse impact on the designated beneficial uses of the waterbodies receiving the runoff.

<u>Toxicity</u> Measure the aquatic life toxicity using larval fish, shellfish and zooplankton in the receiving waters for the runoff associated with runoff events to determine if regulated, as well as unregulated, constituents in the runoff are causing sufficient aquatic life toxicity to be potentially adverse to the designated beneficial uses of the waterbody receiving the runoff.

Bioaccumulation Measure edible tissue residues of non-migratory - resident fish and shellfish populations in the area of the runoff to determine if excessive concentrations of runoff-derived constituents are occurring in edible organisms that cause the organisms' tissue to receive a consumption health advisory. Also, consider the concentrations of chemical constituents in the whole organism that represent potential problems for wildlife that use the organism as food based on the US EPA's Great Lakes Initiative wildlife-based criteria. The focus should be on actual tissue residues in fish that are used as wildlife food and not on chemical concentrations in the water that, under certain conditions, can lead to excessive concentrations of the chemical constituent in fish or other aquatic life that, in turn, represent hazards to wildlife through the consumption of the aquatic life.

Sanitary Quality In order to assess whether the sanitary quality of the receiving waters associated with stormwater runoff from a particular area is significantly adversely affecting contact recreation or shellfish harvesting, it is necessary to determine the relative contributions of waterborne pathogenic indicator organisms, such as fecal coliforms, from the runoff compared to other sources. Such information can then be used to assess whether it may be appropriate to consider disinfecting the stormwater runoff to improve the sanitary quality of the receiving waters for the runoff.

Eutrophication To evaluate whether the aquatic plant nutrients, nitrogen and phosphorus compounds in stormwater runoff are contributing to excessive fertilization of the receiving waters for the runoff, it is necessary to estimate the relative significance of runoff-derived available forms of nutrients that control aquatic plant growth in the receiving waters vs. these same forms of nutrients derived from other sources.

Contaminated Sediments In order to evaluate whether stormwater runoff-associated particulate contaminants are causing significant water quality - use impairments in receiving water due to the runoff-derived contaminants' accumulation in receiving water sediments, it is necessary to first determine whether the receiving water sediments are the cause of a significant use impairment of the waterbody in which they are located. If such a use impairment is found, then an evaluation should be conducted of the specific chemical constituent and its form that causes this use impairment and the sources of this chemical constituent. If stormwater runoff is found to be a significant source of the chemical constituent of concern, then the sources of that constituent (specific chemical form) responsible for the use impairment should be determined.

Petroleum Hydrocarbons The potential impact of petroleum hydrocarbons (oil and grease) on receiving water quality should be evaluated on a site-specific basis focusing on determining whether those conditions for petroleum hydrocarbon accumulation are occurring in the receiving waters for the runoff. If accumulation does occur, then the significance of this accumulation needs to be assessed with particular reference to situations in which the accumulation occurs in ecologically sensitive areas that could be significantly detrimental to aquatic life populations, such as through adversely impacting fish spawning or shellfish.

Litter Visual reconnaissance of the receiving waters for the runoff should be conducted to determine if litter is being derived from this runoff which impairs the uses of the receiving waters.

Domestic Water Supply The significance of HSUA runoff as a source of the constituents that cause domestic water supply utility problems in treatment and/or increased costs should be ascertained.

Development of BMPs In developing BMPs to control to the maximum extent practicable the real water quality - use impairment (pollution) of the receiving waters for the stormwater runoff, it is necessary to first find significant pollution of the receiving waters for this runoff. Once this use impairment - pollution has been identified, then site-specific studies need to be conducted to determine the specific sources of the constituents that are present in HSUA runoff that cause the receiving water use impairment. Once these sources have been identified and quantified, then BMPs can be developed to control the constituents of concern at the source to the maximum extent practicable. If source control does not eliminate the significant adverse impact of the constituents in the runoff, then treatment of the runoff with site-specifically developed BMPs should be implemented. This implementation program should be part of an area-wide, watershed based implementation program to control similar types of HSUA runoff.

Ongoing Evaluation Monitoring In order to detect subtle water quality impacts from current stormwater discharges that were not found in the evaluation monitoring initial screening, as well as new water quality problems arising from the introduction of new chemicals or new forms of chemicals into HSUA stormwater runoff, an ongoing evaluation monitoring program should be conducted. Periodically, such as once in every five year NPDES permit period, each of the components of the evaluation monitoring program should be initiated again.

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List of Acronyms

BMP -	Best Management Practices
BOD -	Biochemical Oxygen Demand
CA DHS -	California Department of Health Services
COD -	Chemical Oxygen Demand
COE -	Corps of Engineers
DO -	Dissolved Oxygen
DOC -	Dissolved Organic Carbon
HSUA-	Highway, Streets and Urban Area
MCL -	Maximum Contaminant Level
TDS -	Total Dissolved Solids
TIE -	Toxicity Investigation Evaluation
TOC -	Total Organic Carbon
US ACOE -	US Army Corps of Engineers
US EPA -	US Environmental Protection Agency
VOC -	Volatile Organic Chemicals

Notice

A generic application of the Evaluation Monitoring approach has been developed for a highway runoff situation that discharges stormwater runoff waters to a major river and an estuarine bay. A copy of this example application is available upon request from G. Fred Lee.